PEAK OF FLIGHT

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PEAK OF FLIGHT

Expandable-Foam Core Fins

By Tim Van Milligan

My kids are just like me. They dislike sanding airfoils into fins. We use every short-cut possible to avoid the task. I have even used the laser-engraver that we have here at Apogee Components to burn away part of the wood so there is less sanding to do (https://www.apogeerockets.com/downloads/2015_streamlining_fins_with_a_laser.pdf).

In this article, I'll tell you my process for making fins that need hardly any sanding at all. They are molded with urethane expandable foam inside a shell made from paper. The result is a lightweight fin that looks great, as seen in **Figure 1**.

Figure 1: Foam fins used on model rockets

Balsa wood is one of my favorite building products. It's strength-to-weight is incredible, and it is easy to work with because it shapes easily and can be glued and painted. However, the one problem with sanding it, besides being time consuming and monotonous, is that you can never be sure that all the fins have the identical airfoil sanded into them. In most model rockets this isn't a huge issue, because the rockets only have to go "fairly straight" when launched to be safe and successful.

Molded plastic fins are uniform in shape, but typically they are heavy and therefore limit the altitude of the rocket. However a fin with a tough skin bonded to a lightweight molded foam can be strong, lightweight, and have a consistent shape from fin to fin. That was the goal of my experimentation last summer when my daughters were getting ready to attend the World Space Modeling Championships in Ukraine. It especially solved the one issue they hated to deal with, which was sanding them to shape.

The Mold

The drawback of molded fins is that they require a special mold. Creating the mold is the hardest part of the process. But once you have it made, the individual fins can be manufactured quickly.

I started the process of designing the fin in a CAD program on my computer. In Peak-of-Flight Newsletter #408 (https://www.apogeerockets.com/education/downloads/Newsletter408.pdf) I talk about the software, and how you often have to design in the 3D environment by removing material. That is exactly how the mold was designed. I designed the fin first, and then used that as a pattern to remove material from the parts that make up the walls of the mold.

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Newsletter Staff
Writer: Tim Van Milligan
Layout/Cover Artist: Chris Duran
Proofreader: Michelle Mason

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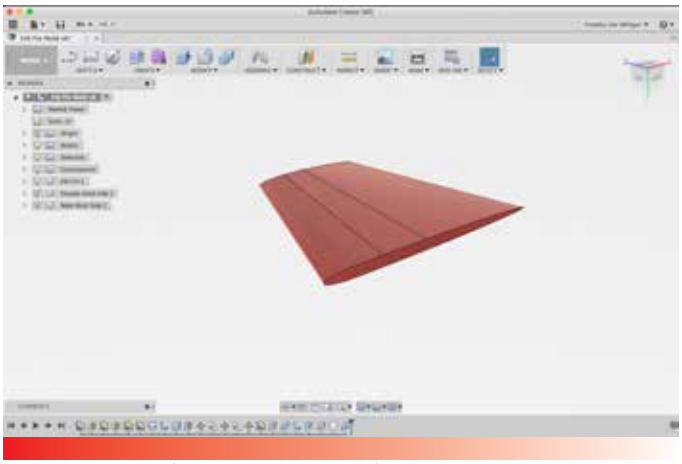

Figure 2: The fin was designed first so it could be used as a tool.

The mold also had location pins added to the side to keep the plates aligned during the molding process.

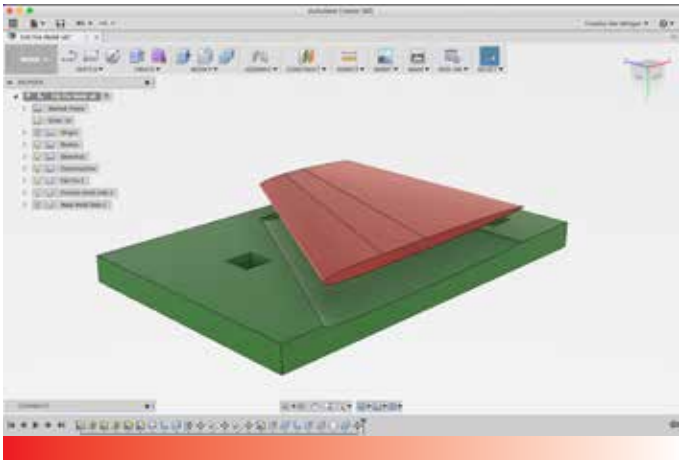

Figure 3: The mold sides were designed using the 3D CAD software.

The next step was to 3D print the molds. If it wasn't for the 3D printing process, I don't think I would have experimented with making fins this way. When I was doing this process, I was under a severe time crunch because we had to have the models built in time to leave on the trip for the competition. I was more concerned about the other aspects of the contest like making the fiberglass body tubes, which was discussed in Peak-of-Flight Newsletters #430, #431, #432, and #434 (https://www.apogeerockets.com/Peak-of-Flight?pof_list=archives&m=education). My backup plan if this didn't yield anything useful was to just make balsa wood fins.

By 3D printing the molds, I was able to test several different ideas in just a few days.

As you may have seen with 3D printed parts, the surface isn't totally smooth. It has layers, like terrace farming. You have to come back and either sand out the little ridges, or try to fill them with some type of filler material. I chose to sand them out. The finished molds are seen in **Figure 4**.

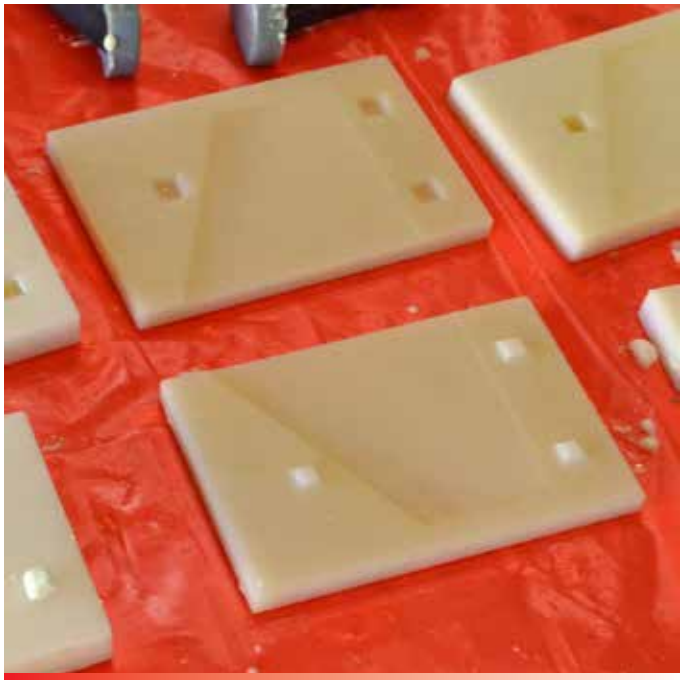

Figure 4: The 3D printed molds

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Pouring the foam

The process of molding fins with the grow foam is pretty easy. You simply pour in some mixed foam into the halves and bring them together. I used a clamp to hold them together while the foaming process took place.

Figure 5: Mixing up the foam in a disposable cup. You have to mix thoroughly but quickly.

Figure 6: The foam expands 25 times its original volume within 20 seconds.

The foam expands to fill all the nooks and crevices, and the excess comes out of the side of the mold with the vent hole. In my molds, the vent is the root edge of the fin as shown in **Figure 7**.

Figure 7: The excess resin oozes out of the vent hole, which in this mold was the root edge of the fin.

My first experiments dealt with different mold releases, just like I had to do when I was making the fiberglass tubes. The urethane foam is very sticky, and if you don't have a mold release on the surface of the mold, you won't get the part out. In the end, the wrong release means you'll have to spend a lot of time scraping it off. It is easy to damage the 3D printed mold because it is made out of a plastic resin itself. I knew the hazards of not having a good mold release because we make the foam nose cones for TARC competitors (https://www.apogeerockets.com/Building_Supplies/Nose_Cones/Low_Mid_Power_Nose_Cones/56mm_Foam_Nose_Cone) in much the same manner. The difference is that this is a rigid foam, so it isn't very forgiving of mistakes.

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The liquid silicone mold release worked best, and the parts would almost jump out of the mold. But the greasy finish was something I didn't like. I know that silicone is hard to remove, and if you don't get it all off, then whatever glue you use to attach the fins to the rocket won't really stick. I couldn't risk the fins falling off in flight with the competition models we were building.

While playing with mold releases, my first experiment was just to grow the foam in the molds by themselves. But the results weren't what I was hoping for. The biggest problem was that the fins were very weak. The foam by itself has no bending strength. It would simply crack in half if you tried to flex it. This would not do for a rocket, because if they cracked in flight from flutter, then the rocket would go unstable.

The other issue that I didn't like was the surface finish. While it was smooth, you could tell that some of the bubbles in the foam had popped on the surface, so it was slightly irregular. Not bad, but not good enough for what I wanted.

My next experiment was to put a small balsa wood core in the mold for the foam to grow around. The hope was that it would stiffen up the foam. The problem was that when the resin would foam up, it pushed out the wooden core - or enough to make the rest of the fin weak.

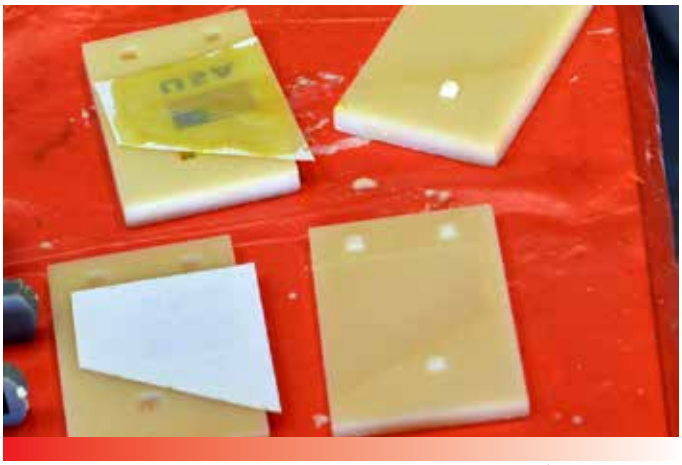

Figure 8: The paper skins laid into the mold before the resin was applied.

I then tried putting paper skins in the mold. And this worked great.

I simply cut a paper pattern just slightly bigger than the fin, and laid it into the mold. I buttered up the paper with foam mix (as shown in **Figure 8**), and laid another sheet on top and closed the mold.

After about 20 minutes, the foam is hard and the part can be removed from the mold. The first thing I do is to cut off the excess with a razor blade as seen in **Figure 9**. The foam cuts really easily, but it helps to have a very sharp blade in order to slice through the paper without tearing it.

The edge of the mold is used as a straight edge, so the edge is actually good enough to use when attaching it to the rocket.

Figure 9: Cut off the excess foam with a sharp razor blade.

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To open the mold, I use the razor blade and wedge it between the two halfs of the mold as shown in **Figure 10**. You have to be careful here not to cut into the fin itself. I just get it in a little bit, and twist it gently so the mold halves separate.

Figure 10: The mold halves are opened by sliding a razor blade in the gap.

With the paper skins in the mold, the two halves open very easily. But you still have to use mold release in cavity of the mold because some foam does leak out between the skins around the entire perimeter.

Therefore, the edges of the paper are not perfect as they come out of the mold and they do have to be trimmed with a hobby knife and a straight edge. The paper can shift a little bit too inside of the mold because of the foaming and flowing material.

Figure 11 shows the completed fin after it has been trimmed and attached to the rocket. The leading edge is fairly sharp because that is where the paper skins come together. Ideally, you want the leading edge of the fin to have a rounded edge, like shown in **Figure 2 (Page 3)**.

Figure 11: The finished fin has a pillow like quality, with sharp edges around the perimeter.

The edge can be sanded so that it is round, but that is going to expose the foam inside the fin. Since the foam is rough when sanded, you'll end up with a rough leading edge of the fin. So on the competition models my daughters' used in Ukraine, they had sharp edges as shown here.

One thing that I didn't have a chance to test was to use a folded piece of paper on the leading edge to see if that would help round off the edge like I wanted. Someday, I'll have to play with that.

The other cool thing, as you can see here, is that you can pre-print a pattern on the paper prior to putting them into the mold. That allows you to customize the look of your rocket without having to paint it later.

The outer texture of the paper will be the surface finish of your completed rocket. If you use ordinary bond paper like I did for the ones in **Figure 11**, it will have a dull appearance.

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It is possible to use other papers and different materials. In **Figure 12** I test aluminized mylar and it worked well. You do have to start with a piece of mylar that has no crinkles in it. The foam doesn't push out all the little wrinkles. And the edge is a little harder to work with, because you can't sand the mylar. So you have to trim it very carefully when it comes out of the mold.

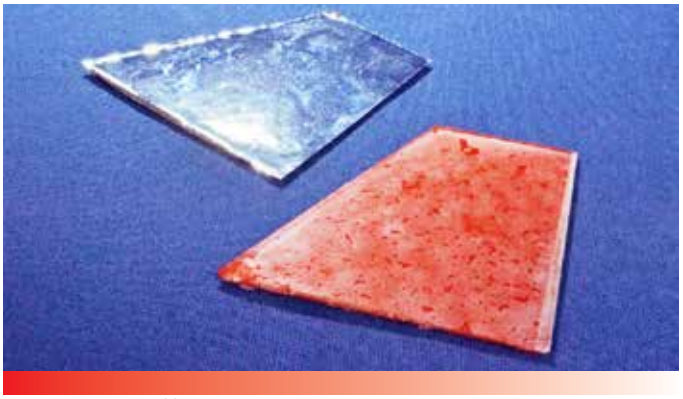

Figure 12: Different skin materials can be used to make foam fins. Here are aluminized mylar and tissue paper.

Tissue paper also works well for the skins. I tried the material because I wanted to see how light I could make a fin. Tissue paper was the lightest weight, with a fin coming out about 0.3 grams.

There are a couple of disadvantages of tissue paper as a material. First, the fin is more flexible and not as strong as one made from bond paper. If the rocket's speed is fairly slow like the A-engine powered rockets that I was flying, this is fine. My daughters used tissue paper skinned fins in competition, and they worked just fine.

The other issue is that the resin will push through the looser weave and get to the surface of the fin. That ruins the look of the fin, and as seen in **Figure 12**, the smoothness isn't quite as nice.

One discovery I made is that if you use the liquid silicone release with the tissue paper, the silicone soaks into the tissue and prevents the urethane resin from making its way to the surface. You just have to clean them really good after they come out of the mold to make sure the silicone is removed so that they glue will stick them to the tube of the rocket.

Conclusion

While I was making foam fins for competition style rockets, I'm sure that they would be even better for sport rockets where it doesn't matter as much what airfoil shape is used. I would say they could also be used to make scale model fins, like the wedged shaped fins on a Nike-Smoke rocket.

For the competition rockets like I was making, I'm still a little bit undecided if I'd use them again. They worked, but one thing that I discovered was that the weights were not as uniform as I wished. That means that the density of the foam can vary from one fin to the next. I wish for a bit more consistency, along with a better leading edge. But I did like that I could pre-color the fin with a printed pattern on it. It really helped our rockets to stand out.

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Resources:

Rigid Foam -
https://publicmissiles.com/product/adhesives
https://bjbenterprises.com/index.php/polyurethanes/foams/rigid/tc-300-a-b/

Mold release: https://bjbenterprises.com/index.php/misc-products/release-agents/partall-hi-temp-mold-release-wax-3059/

About The Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. He is an avid rocketry competitor, and is Level 3 high power certified. He is often asked what is the biggest rocket he's ever launched. His answer is that before he started writing articles and books about rocketry, he worked on the Delta II rocket that launched satellites into orbit. He has a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University in Daytona Beach, Florida, and has worked toward a M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida. Currently, he is the owner of Apogee Components (http://www.apogeerockets.com) and also the author of the books: Model Rocket Design and Construction, 69 Simple Science Fair Projects with Model Rockets: Aeronautics and publisher of the "Peak-of-Flight" newsletter, a FREE e-zine newsletter about model rockets. You can email him by using the contact form at: https://www.apogeerockets.com/Contact.